REMARKS

Claims 1-23 are pending in the application Claims 1-6, 8-16, 18-19, and 21-23 have been amended. Claims 2-6, 8-16, 18-19, and 21-22 have been amended to improve their form by replace the article "said" with "the." No new matter has been added as a result of this amendment.

Rejection Under 35 U.S.C. §102(b)

Claims 1, 2, 5, 8-12, 14-18, and 21-23 have been rejected over Agarwal et al. This rejection is overcome in view of the amendment of claims 1 and 23, together with the following remarks.

Claim 1, as amended, recites a method for fabricating a thin layer by implanting a first chemical species in a substrate at a first depth to form a weak buried region. At least one second chemical species is implanted in the substrate at a second depth different from the first depth, and at a higher atomic concentration than the first chemical species. The second chemical species resides outside of the weak buried region. The method also includes diffusing at least a portion of the at least one second chemical species from the second depth into the weak buried region. Then, the thin layer is fabricated by initiating a fracture along the first depth. The applicants' assert that Agarwal et al. do not suggest or disclose the method recited by claim 1.

The difference in implantation depth of the first and second species recited by claim 1 can be appreciated from the applicants' specification, in which the applicants describe and illustrate the diffusion of chemical species from a secondary depth peak (3) to the level of a main peak (5). (See Fig. 3b, and pg. 9, ll. 30-35, pg. 10, ll. 1-15). The applicants describe an embodiment of their invention in which helium atoms and hydrogen atoms are implanted in a silicon substrate. (Pg. 13, ll. 10-29). In the disclosed embodiment, helium is implanted at an energy of 180keV, while hydrogen is implanted as an energy of 75keV.

Agarwal et al. disclose implanting H^+ at 30 keV and He^+ at 33 keV. In one disclosed combination, H^+ is implanted at a dose of 7.5 E15 and He^+ is implanted at a dose of 1 E16. Agarwal et al. is acknowledged prior art in the applicants' specification.

The applicants describe this reference as follows:

> The paper "Efficient production of silicon-on-insulator films by co-implantation of He^+ with H^+" by Agarwal et al. (Appl. Phys. Lett., Vol. 72, No 9, March 1998) describes a method comprising the co-implantation in a silicon substrate of two chemical species, namely hydrogen and helium. The authors specify that the implantation profiles of the two implanted species must be localized to the same depth. It is thus possible to reduce the total dose implanted and enabling subsequent fracture, compared to using either of the two chemical species alone: according to the authors, this technique reduces the total dose implanted by an amount of the order of 50%. The authors also disclose that the order in which the two implanted species are implanted is important: the hydrogen must be implanted first, and the helium second; they assert that if the helium were implanted first the reduction in the total dose implanted would be less. (Specification, pg. 3, ll. 28-35; pg. 4, ll. 1-5).

The Examiner asserts that Agarwal et al. disclose implanting hydrogen and helium, and that the hydrogen and helium are implanted a different depths in the substrate. (Office Action, pg. 2). As noted in the application text shown above, the applicants do not agree that Agarwal et al. disclose implanting hydrogen and helium at different depths in the substrate. Instead, the applicants assert that Agarwal et al. disclose implanting both species at the same depth. In a technical article published in 1998 by four of the same authors with two different authors, the implantation of hydrogen at 30 keV and helium at 33 keV is described as producing an overlapping profile at a depth of 0.4 um. See "The Role Of Implantation Damage In The Production Of Silicon-On-Insulator Films By Co-Implantation of He^+ and H^+," Venezia et al. (attached). This reference will be formally cited in the applicant's forthcoming Supplemental Information Disclosure Statement that will shortly follow this response. The applicants assert that the process described by Venezia et al. is substantially similar to that disclosed in Agarwal et al.

The applicants assert that there is no basis for the Examiner's assumption that the subject matter disclosed by Agarwal et al. describes implantation of hydrogen and helium at different depths in the substrate. Claim 1 recites a process in which the second species resides outside of weak buried region, then a diffusion process is

carried out to diffuse the second species into the weak buried region. Thus, neither Agarwal et al. nor Venezia et al. suggest or disclose the method of fabricating a thin layer recited by claim 1.

The applicants assert that their claim sets forth a relationship in which the second chemical species is less effective than the first chemical species at weakening the substrate. As explained by the applicants, the implantation of the first chemical species localizes the fracture that will subsequently be initiated and allows the transfer of a thin surface layer. The second species provides a reservoir that can migrate to the fracture cite to facilitate the fracture of a substrate. (See, for example, pg. 6, ll. 31-35, pg. 7, ll. 1-24). The migration of a second species to the fracture zone allows the growth of microcavities, without increasing the size of the disturbed region. This results in an improved process in which a precise fracture of the thin film occurs. (See, for example, pg. 12, ll. 5-31, pg. 13, ll. 7-29). Agarwal et al. do not mention any details regarding a technique to improve the quality of the thin film. Instead, as described by the applicants in their specification, Agarwal et al. teach that implanting hydrogen and helium reduces the total implant dose compared to using either of the two chemical species alone.

Claims 2 depends from claim 1 and recites a particular depth relationship between the first and second species in which the second species is at a greater depth than the first species. As asserted above, Agarwal et al. disclose implanting hydrogen and helium at the same depth, not different depths as recited by claim 2. This stands in sharp contrast to the method of claim 2. As described above, in an exemplary embodiment illustrated in FIGs. 3a-3d of their drawing, the applicants illustrate a method in which a secondary species (3) is implanted into the substrate, followed by a primary species (4). The primary species is implanted to a depth (5) that is less than the secondary species. The secondary species is then diffused into the region of the substrate occupied by the primary species. Claim 2 is allowable in view of the failure of Agarwal et al. suggest or disclose the claimed method.

Claim 5 is allowable at least in view of the amendment and remarks pertaining to claim 1 from which it depends.

Claims 8-9 and 21-22 recite thermal budget relationships as a result of the implanting a second species. This is a particular advantageous aspect of the

applicants' claimed method that results in less thermal energy needed to fabricate the thin layer. (Specification, pg. 8, ll. 11-22). The Examiner cites particular time/temperature conditions described by Argarwal et al. and, by way of contrast with a comparative example described by the applicants, concludes that Agarwal et al. discloses a reduced thermal budget. (Office Action, pg. 3). Thus the Examiner attempts to use the applicants' own specification to supplement the teaching of Agarwal et al. The applicants assert that Argarwal et al. do not disclose thermal budget relationships associated with the method recited by claim 1. Further, there is no disclosure of additional amounts of a second chemical species, as recited by claim 9. Agarwal et al. is teaching a reduction in the needed quantities of implanted species, not the use of additional amounts. Accordingly, claims 8-9 and 21-22 distinguish over Agarwal et al.

Claim 10 depends from claim 5 and recites different heat treatment methods. This claim is allowable at least in view of the amendment and remarks pertaining to claim 1 from which it indirectly depends.

Claims 11-12 depend directly and indirectly from claim 1, respectively, and recite application of mechanical stress to initiate the fracture of the thin layer. The applicants do not understand Agarwal et al. to disclose a facture process as set forth by claim 1. This reference discloses application of a handle wafer, but once the handle wafer is bonded, the wafers are cut into pieces. The description by Agarwal et al. of a shear process is in reference to the prior art process of Bruel, cited by the applicants in their specification at page 2, lines 31-35. Agarwal et al. are not describing an improved thin layer formation process as recited by claim 1. Accordingly, claim 11-12 distinguish over Agarwal et al.

Claims 14-18 depend directly or indirectly from claim 1. These claims are allowable at least in view of the amendment and remarks pertaining to claim 1.

Claim 23, as amended, recites a method similar to claim 1, with the additional feature that the method is carried out by either applying a heat treatment for less time and at a lower temperature then that necessary in the absence of step b), or by implanting an additional amount of the at least one second chemical species to avoid exceeding a predetermined time/temperature regime. The applicants assert that

Agarwal et al. do not disclose thermal budget relationships associated with the method recited by claim 23. Nor do Agarwal et al. disclose additional amounts of a second chemical species. Accordingly, claim 23 distinguishes over Agarwal et al.

Rejection Under 35 U.S.C. §103(a)

Claim 3 has been rejected over Agarwal et al. in view of Weldon et al. and Wang. This rejection is overcome in view of the amendment of claim 1, together with the following remarks.

Claim 3 depends from claim 1 and recites that the method includes implanting the second species to a depth less than the first species. As described by the applicants, this method can be important where a defect layer is desired. The defect layer can have electrical insulation or trapping properties, or both. (Specification, pg. 7, ll. 30-34). The applicants assert that the addition of Weldon et al. and Wang does not overcome the deficiency of Agarwal et al. Although Weldon et al. disclose implanting at different depths, none of the cited references suggest or disclose the method recited by claim 1, as supplemented by claim 3.

Wang disclose implantation of dopant atoms in semiconductors. The applicants assert that dopants operate to change the electrical characteristics of semiconductors. This is not related to the applicants' claimed thin layer fabrication at least because diffusion of implanted dopant atoms is not desired.

Claims 4 and 19 have been rejected over Agarwal et al. in view of Duo et al. This rejection is overcome in view of the amendment of claim 1, together with the following remarks.

Claim 4 depends from claim 1 and recites that the second chemical species is implanted before the first chemical species. The order of implantation can be important. As described by the applicants:

> "Accordingly, during step c), [diffusion of the secondary species] the tendency to diffuse away from its implantation peak is stronger for the secondary species than for the main species, precisely because the secondary species is less effective than the main species. The secondary species, in the form of concentrated free gas, is then accommodated in the microcavities previously created by the main implantation, and

> encourages the growth of the microcavities, without at the same time increasing the size of the disturbed region at the level of the main peak." (Specification, pg. 7, ll. 17-24).

In contrast, as pointed out by the applicants in their specification, Agarwal et al. discloses the opposite implant order. Agarwal et al. "disclose that the order in which the two implanted species are implanted is important: the hydrogen must be implanted first, and the helium second:..." (Specification, pg. 3, ll. 28-35; pg. 4, ll. 1-5). In the case of helium and hydrogen, the helium is less effective than hydrogen at weakening the substrate. Agarwal et al. do not recognize the significance of the implant order described by the applicants and recited by claim 4. Claim 4 distinguishes over Agarwal et al. at least because claim 4 recites the opposite implant order relationship.

The applicants assert that the addition of Duo et al. does not overcome the deficiency of Agarwal et al. Duo et al. investigated the order of implantation of helium and hydrogen with respect to density of atoms and positron traps. (Abstract). Duo et al. concluded that helium-implanted first samples, the helium could not move to the hydrogen-distributed region. (Pg. 482, first column). Duo et al. ultimately concluded that "[i]t is not so efficient to exfoliate the surface in the samples implanted with helium first than in the samples implanted with hydrogen first." (Pg. 482, second column). Accordingly, the applicants assert that Duo et al. teach the opposite implantation order compared to claim 4.

Claims 6-7, 13, and 20 have been rejected over Agarwal et al. in view of JP11087668 to Kenji. This rejection is overcome in view of the amendment of claim 1, together with the following remarks.

The applicants forgoing remarks pertaining to claim 1 and Agarwal et al. are incorporated herein. As previously asserted by the applicants, Kenji implants chemical species into the same region of the substrate. The applicants remarks regarding Kenji set forth in their previous response of May 19, 2009 are incorporated herein.

Claims 6, 7 and 20 relate to inducing migration and fracture. The diffusion and heat treatment elements of the applicants claimed method operate to provide an improved thin film fabricating method. As explained by the applicants, the implantation of the first chemical species localizes the fracture that will subsequently be initiated and

allows the transfer of a thin surface layer. The second species provides a reservoir that can migrate to the fracture cite to facilitate the fracture of a substrate. (See, for example, pg. 6, ll. 31-35, pg. 7, ll. 1-24). The migration of a second species to the fracture zone allows the growth of microcavities, without increasing the size of the disturbed region. This results in an improved process in which a precise fracture of the thin film occurs. (See, for example, pg. 12, ll. 5-31, pg. 13, ll. 7-29). The applicants assert that these claims are not suggested or disclosed by the combination of cited references.

Claim 13 depends from claim 1 and recites a method that includes applying a thickener to support the thin layer after fracture. The applicants remarks pertaining to Agarwal et al. are incorporated herein. As best understood by the applicants, in FIG. 2, Kenji is describing air bubbles that form blisters on the surface of an oxide layer (11a). The process disclosed by Kenji is shown in the sequence illustrated in FIG. 1, in which a support board (12) is applied to the implanted wafer. Accordingly, neither of the cited references discloses the method of claim 1, with the additional features of claim 13.

The applicants have a made a novel and nonobvious contribution to methods for fabricating thin film layers. The claims at issue distinguish over the cited references and are in condition for allowance. Accordingly, such allowance is now earnestly requested.

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THE ROLE OF IMPLANTATION DAMAGE IN THE PRODUCTION OF SILICON-ON-INSULATOR FILMS BY CO-IMPLANTATION OF He^+ AND H^+

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ABSTRACT

Recent work has demonstrated that the process of silicon thin-film separation by hydrogen implantation, as well as the more basic phenomenon of surface blistering, can occur at a much lower total dose when H and He are co-implanted than when H is implanted alone (1). Building on that work, this paper investigates the role of implantation damage in this process by separating the contributions of gas pressure from those of damage. Three different experiments using co-implantation were designed. In the first of these experiments, H and He implants were spatially separated thereby separating the damage from each implant. The second experiment involved co-implantation of H and He at a temperature of 77 K to retain a larger amount of damage for the same gas dose. In the third experiment, Li was co-implanted with H, to create additional damage without introducing additional gas. These experiments together show that increasing the implantation damage itself hampers the formation of surface blisters, and that the increased efficiency observed for He co-implantation with H is due to the supplementary source of gas provided by the He (1).

INTRODUCTION

There is great deal of interest in a new process that uses H implantation to produce thin silicon-on-insulator (SOI) films (2). In this process, a surface layer of a silicon wafer, implanted with H^+, is transferred onto an oxidized wafer after the two wafers are bonded together and annealed (2). Since the remaining wafer can be re-polished and used again, this process has the potential to produce SOI wafers more economically than competing processes such as high-dose oxygen implantation or bonded-etchback, in which two silicon wafers are consumed to make one SOI wafer.

This process of H-induced, thin-film separation was originally based on the observation that implantation of high-dose H leads to blistering and flaking on the surfaces of metals and semiconductors (3). Bonding to a support wafer confines the fracture in the implanted wafer to a plane parallel to the bonded interface, so that a continuous fracture surface is created rather than isolated blisters.

To understand both the thin-film process and the surface blistering induced by H implantation, Weldon, *et. al*, performed a series of studies in which both the chemical and physical-mechanical effects of the implanted H in silicon were investigated (4). It was found that H-passivated microvoids or platelets are formed as a result of implantation, and that H_2 gas trapped in these microvoids provides the physical pressure necessary to produce the observed surface blistering and flaking. They also demonstrated that blistering and the thin-film separation process are due to the same mechanism, except that in the case of film separation the bonded wafer provides a mechanical constraint that drives the microvoids to grow laterally and intersect to form continuously separated surfaces. Other authors have also concluded that the same process controls both the observed blistering and the thin-film separation because they have the same activation energy (5).

In our previous work (1), we have demonstrated that the total implantation dose needed for surface blistering or thin-film separation can be reduced by greater than 70% by using co-implantation of H and He. Since ion implantation is known to produce damage in silicon, it is also important to understand the role of the ion-induced damage in the co-implantation process. In this work, we investigate the impact of the crystalline damage induced by implantation on the surface blistering phenomenon, and thus the thin-film separation process. We have separated the damage induced by He, the co-implanted ion, from the physical effects of the He gas in the following ways. In one set of experiments, He was implanted deeper than H, separating most of the damage from the He implant from the location of the H implant. The surface blistering did not change when the H and He implants were spatially separated, indicating that the damage induced by the He implant played little role in improving the efficiency of the formation of surface blisters. Experiments were also performed in which H and He were co-implanted at a low temperature (77K) to produce more crystalline damage for a constant gas content. In this case, the surface blistering was suppressed relative to room-temperature implantation. Co-implantation of Li, instead of He, was also performed to add implantation damage without adding gas. We found that when Li was implanted with a large dose of H, that alone would produce surface blistering, the surface blistering was suppressed.

EXPERIMENT

All studies were performed on Czochralski (CZ) Si(100) substrates. H, He, and Li ions were implanted with energies and doses ranging from 30 to 130 keV and from 1×10^{16}/cm^2 to 1×10^{17}/cm^2, respectively. The H and He doses were chosen from previous work (1) and TRIM simulations were used to determine the dose of Li in order to match the number of displacement collisions to that of the He co-implants. Implants were performed using a Varian Extrion implanter with a 90° magnetic mass analyzer. Implanted samples were subjected to rapid thermal annealing (RTA) at 750°C for 20 s in flowing Ar. The surfaces of annealed samples were imaged using an optical microscope with Nomarski contrast capability. In this work, we take the observation of blistering to be an indication that layer transfer would occur under similar conditions in a bonded-wafer configuration. Defect profiles were determined by ion-channeling measurements using a 2 MeV He^+ beam from a 2.5 MV van de Graaff accelerator. Cross-sectional transmission electron microscopy (XTEM) was also performed on implanted and annealed samples. XTEM samples were prepared by mechanical thinning and Ar^+ ion-beam milling at 77K. Extended defects were imaged using the weakly excited 220 and 400 reflections. Secondary ion mass spectrometry (SIMS) was used to profile He in implanted and annealed samples using a 8 keV O_2^+ sputter beam.

RESULTS

A. Spatial Separation of H and He profiles.

In previous work, we have shown that the surface blistering and flaking that result from a high-dose H (6×10^{16}/cm^2) implant into silicon after an RTA at 750°C for 20 s is also observed at a much lower dose of H (1×10^{16}/cm^2) if a low dose of He (7.5×10^{15}/cm^2) is co-implanted to overlap the H profile. These same doses do not produce surface blistering for either single-species implant. When the energies were 30 keV for H and 33 keV for He, the profiles overlapped at a depth of 0.4 μm and blisters and craters with diameters in the range of 2-5 μm and depths of 0.4 μm were observed after annealing

According to the above results, the addition of a He implant assisted the blistering process when implanted at the same depth as H. However, in that experiment, both the He and its associated damage coincided with the H. To separate the location of the He-induced damage from the H, 30 keV H ions were implanted with 130 keV He ions at doses of 3×10^{16}/cm^2 and 1×10^{16}/cm^2 respectively, and annealed at 750°C for 20s. Figure 1a is an optical micrograph showing the surface blistering that result from these implant

and annealing conditions. For comparison, the results for the same doses of H and He with energies of 30 keV and 33 keV are shown on Fig. 1b. Comparison of Figs. 1a and 1b shows that separating the implant profiles had no significant effect on the surface blistering. Since the blistering remained essentially unchanged as a result of placing the He damage deeper than the H damage, we can conclude that the effects of the damage induced by the He did not play a significant role in enhancing the formation of the surface blisters at lower doses. Another sample was similarly implanted with 3×10^{16}/cm^2 of 30 keV H and 1×10^{16}/cm^2 of 30 keV H, then annealed in vacuum at 450°C for 15 min. Experience has shown that this anneal is just below the threshold for blister formation. SIMS profiles of this sample before and after the 450°C anneal are shown in Fig. 2, where the arrow indicates the depth of the H implant. The as-implanted SIMS depth profile shows that the He distribution is initially very broad and located deeper than the H profile. Upon annealing, the He is observed to be located in a narrow region near the depth of the H implant. Therefore, it is simply the presence of the He gas in the H-rich region that leads to the formation of surface blisters, and presumably makes the thin-film separation process more efficient.

B. Cryogenic Implantation.

It is well known that the amount of residual implant damage is larger at lower implant temperatures. Therefore, we performed another set of experiments in which the same 30 keV 3×10^{16} H/cm^2 and 33 keV 1×10^{16} He/cm^2 were co-implanted into silicon at 77K. In this way, we increased the amount of implant damage for a fixed gas content. Figure 3 is an optical micrograph of the 77K implant after RTA at 750°C for 20s. Figure 3 illustrates that the low implant temperature suppressed the surface blistering previously observed in Fig. 1b. Ion channeling (Fig. 4) confirmed that implantation at 77K created a much larger amount of damage to the silicon lattice than did room-temperature implantation. These experiments demonstrate that increasing the amount of implant damage for a fixed H and He gas content is detrimental to the formation of the surface blisters.

C. Co-implantation with Li^+.

Implant damage was also introduced by co-implantation of Li instead of He. A dose of 8×10^{15}/cm^2 of 50-keV Li was co-implanted with 1×10^{17}/cm^2 of 30-keV H. The dose of the Li implant was chosen to match the damage induced by a 1×10^{16}/cm^2 He implant, as calculated by TRIM. TRIM simulations of the displacement distributions for the He and Li implants are compared in Fig. 5. Figure 6a is an optical micrograph of the surface of a silicon substrate following co-implantation of Li with H and RTA. Figure 6a can be compared to Fig. 6b, which shows the corresponding result for the 1×10^{17}/cm^2 H implant without a Li co-implant. Co-implantation with Li clearly suppresses the formation of the characteristic surface blisters. Ion channeling (Fig. 7) shows that the Li^+ implant induced much more damage than the He implant. These experiments demonstrate that increasing the amount of damage for a fixed amount of H gas hampers the formation of blisters, similar to the above case of cryogenic H and He co-implantation.

CONCLUSIONS

The role of implant damage in the thin-film separation process that uses co-implantation of H and He was investigated by separating the contributions of gas pressure and implantation damage. The presence of He in the region of the H implant was shown to make the process of surface blistering more efficient. When the amount of damage was increased for a fixed gas content, either by reducing the implantation temperature or by adding a Li co-implant, the formation of surface blisters was suppressed. These experiments, as well as previous work, suggest that the essential role of H is to chemically interact with implantation damage to create a high density of microvoids, which are plate-like cracks whose internal surfaces are likely to be H-passivated (4). The presence of H is expected to aid the crack formation process by reducing the surface free-energy density of the new internal surface area produced during crack growth. While H is efficient at forming the required high density of microvoids due to its propensity to passivate dangling bonds in silicon, we argued that the same chemical interaction hampers segregation of excess H into the voids and formation of H_2 gas for two reasons. First, all of the broken bonds created by energetic collisions during the implantation can compete for the available H and many of these may not be associated with microvoids. Furthermore, H diffusion in Si is known to be severely limited by defect traps (6), (7). Consequently, when H is implanted alone, a larger dose of H is necessary to produce the excess H_2 gas pressure needed for surface blistering. However, He is not as readily trapped by dangling bonds and can more easily diffuse into the microvoids, providing the force that drives crack growth leading to exfoliation.

ACKNOMLEDGEMENTS

Research at Oak Ridge National Laboratory was sponsored by the U. S. Department of Energy, Office of Energy Research, Laboratory Technology Division and the Division of Materials Sciences under contract DE-AC05-96OR22464 with Lockheed Martin Energy Research Corp. Two co-authors were also supported by Oak Ridge

Associated Universities fellowships under contract DE-AC05-76OR00033 with the U.S. Department of Energy.

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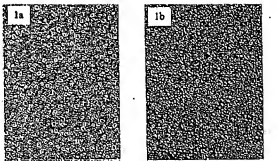

Figure 1. Optical micrograph of the surface of Si(100) implanted with a) 30 keV $3x10^{16}$ H/cm^2 + 130 keV $1x10^{16}$ He/cm^2 and b) 30 keV $3x10^{16}$ H/cm^2 + 33 keV $1x10^{16}$ He/cm^2 and annealed at 750°C/20 s.

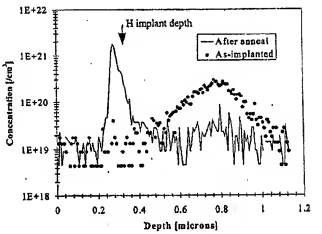

Figure 2. SIMS concentration profile vs depth for 30 keV $3x10^{16}$ H/cm^2 + 130 keV $1x10^{16}$ He/cm^2 annealed at 450°C / 15 min.

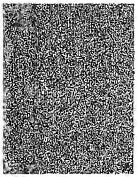

Figure 3. Optical micrograph of the surface of Si(100) implanted with 30 keV $3x10^{16}$ H/cm^2 + 30 keV $1x10^{16}$ He/cm^2 at 77 K and annealed at 750°C/20s.

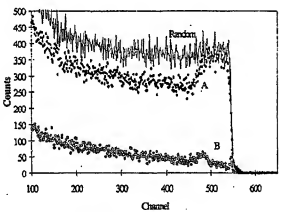

Figure 4. Channeling spectrum of Si(100) co-implanted with 30 keV H $3x10^{16}$/cm^2 and 33 keV He $1x10^{16}$/cm^2 at a) 77 K and b) RT

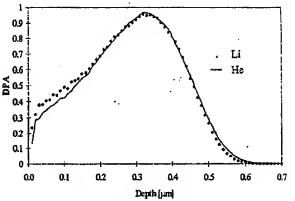

Figure 5. TRIM simulation of damage induced in silicon by a 33 keV $1x10^{16}$/cm^2 He$^+$ implant and by a 50 keV $8x10^{13}$/cm^2 Li$^+$ implant.

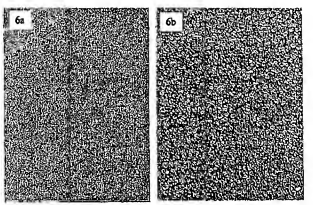

Figure 6. Optical micrograph of the surface of Si(100) implanted with 30 keV $1x10^{17}$ H/cm^2 + 50 keV $8x10^{15}$ Li/cm^2 and b) 30 keV $1x10^{17}$ H/cm^2 and annealed at 750°C/20s.

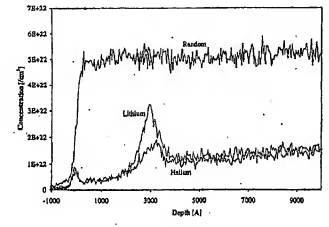

Figure 7. Channeling spectrum of Si(100) implanted with 1) 33 keV He $1x10^{15}/cm^2$ and 2) 50 keV Li $8X10^{12}/cm^2$. A random spectrum is included for reference.

Effect of ITOX-process on the Electrical Characteristics of Buried Oxide in low-dose SIMOX

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ABSTRACT

The quality of low-dose SIMOX buried oxide formed by ITOX-process was investigated electrically and compared with that without ITOX-process. The onset of current leakage for the buried oxide with and without ITOX-process was observed at a lower electrical field (2-3 MV/cm) than that for the HTO film. This was due to the lowering of Fowler-Nordheim barrier heights which was caused by the silicon-rich region included in the buried oxide layer. This silicon-rich region was located in the upper region of the buried oxide. After ITOX-process, the silicon-rich region moves inside the buried oxide and its density reduced. The quality of the buried oxide is improved by ITOX-process, but not enough compared to that of HTO film.

INTRODUCTION

Separation by implanted oxygen (SIMOX) is an excellent technique for fabricating the silicon-on-insulator (SOI) substrates that will be used for future low-power and high-speed active devices. The high conductive current through the buried oxide (BOX) layer in high-dose SIMOX exhibits distinctly different characteristics than that through thermal oxide, because silicon-islands are included in the BOX layer[1]. It has been reported that the densities of silicon-islands and the pin holes were reduced[2] in the low-dose SIMOX and the interface morphology between the top Si layer and the BOX layer was improved by using internal thermal oxidation (ITOX)[3]. However, the resulting reliability of the BOX layer (i.e., the electrical isolation between the top Si layer and the base Si substrate) remained unclear.

In this work, we have investigated the reliability of the BOX layer electrically. First,